Inquiry: The University of Arkansas Undergraduate Research Journal

Volume 5 Article 15

Fall 2004

Last Frost Project

Midori Kubozono
University of Arkansas, Fayetteville

Last Frost Project

Midori Kubozono

Faculty Mentor: Craig W. Thompson

1.0 Abstract

For nursery stores and garden shops planning Spring deliveries, it is crucial to be able to predict last frost dates for frost-tolerant and frost-tender plants. This project provides historically reliable information on the seasonal last frost occurrence for U.S. store locations. Stores can use this information as a general guide in making Spring distribution plans but would also need to take the current season's weather variations and predictions into account.

Using geospatial software and an historical weather data set provided by National Climatic Data Center, the probability from 10 percent to 90 percent for days below a specified temperature (i.e., 28 ^{o} F. and 32^{o} F.) is visualized as zoning maps. The weather data set covers over 3,000 weather stations in the United States from 1951 to 1980.

After creation of the maps, accuracy of the approach is considered from the aspects of geographic conditions and actual planting dates for frost-tolerant and frost-tender plants.

2.0 Objective

The objective of this project is to obtain reliable information on the seasonal last frost occurrence in the United States and to create a guide to help nursery stores make distribution plans for frost-tolerant plants and frost-tender plants. The information from this project would be useful for nursery stores because it keeps stores from putting "live goods" into the stores when we still have a high probability for a killing frost. This potentially saves stores and customers from losses due to stocking or planting too early in a growing season.

3.0 Approach

3.1 Definition of Frost

Understanding terminology and the concept of "killing frost" and "frost" is a first step for this project. Scientifically, there is no exact definition for "killing frost" due to the fact that different plants have varying tolerances for cold temperatures. According to Dr. Klingaman in the Horticulture Department of University of Arkansas, there is a useful distinction between "frost tender plants" and "frost-tolerant plants." He indicates that, in Fayetteville, the safe planting date is considered to be between March 25 to 30 for frost-tolerant plants (broccoli, onions, pansies, primroses, etc.) and between April 15 and April 20 for frost-tender plants (tomatoes, most spring bedding plants). That is a broad range of dates, indicating plant sensitivity to temperature and annual variations in weather.

The definition of "frost day" is also somewhat arbitrary, depending upon the accepted criteria for a frost observation. Adopted the commonly accepted definition, we conservatively take the definition of "frost day" to be a day with minimum temperature below 32F degree. We also consider a day with temperature below 28F degree as "high risk of killing frost."

3.2 Data Sources

Two main datasets were used in this project: weather station locations and weather observations [1]. The weather station location data set consists of an historical station index with extensive station information such as observation period, latitude, longitude, and elevation. The data set is available from National Climatic Data Center (NCDC). The weather data set used for this project is *Probability Levels For Freeze Dates and Growing Season Length*s (Data set 9712C). This data set, also available from NCDC, is the computation of the derived statistics performed for 3,240 weather stations in the United States for observational data covering the 1951-1980 period. The data set contains probability levels (10, 20, 30, 40, 50, 60, 70, 80, 90 percent) for each low temperature thresholds (36, 32, 28, 24, 20, 16 F. degrees). For our project, we used data of the all probability levels and temperature thresholds 32^{o} F and 28^{o} F according to our definitions of “frost day” and “high risk of killing frost.”

3.3 Software

For this the project, we used two databases and a geospatial application: MySQL, Microsoft Access (Access) and ESRI ArcMap. MySQL was used to convert the original data sets into queryable form from its plain text file format. Nevertheless, from the aspect of compatibility of data with ArcMap, Access was more suitable than MySQL because ArcMap directly supports the Access database format. Therefore, we converted the tables in MySQL into Access. Then we analyzed and visualized the data using ArcMap.

3.4 Method

The project objective is to determine probabilities of last frost dates in the United States by weather stations and visualize the result using geospatial maps. To do this, after some searching, a directly usable data set from NCDC was located as described above. The software described above was used to generate two kinds of maps with the expectation that these maps would help nursery stores make distribution plans for frost-tolerant and frost-tender plants. Zoning maps, generated from 3106 weather stations’ data, were classified into two week ranges. County level maps were then created based on the data from the zoning maps. These latter maps were based on the mean date for each county. Zoning maps and county level maps were created for the conterminous United States and Alaska, for 28F degree and 32F degree thresholds, from

10% to 90%. The next step was to confirm reliability and accuracy of these maps by checking geographical conditions (e.g., elevation) of the subject area. Finally, we compared the data we obtained in this project and the information from horticulture expertise of University of Arkansas about the planting date for frost-tender plants and frost-tolerant plants.

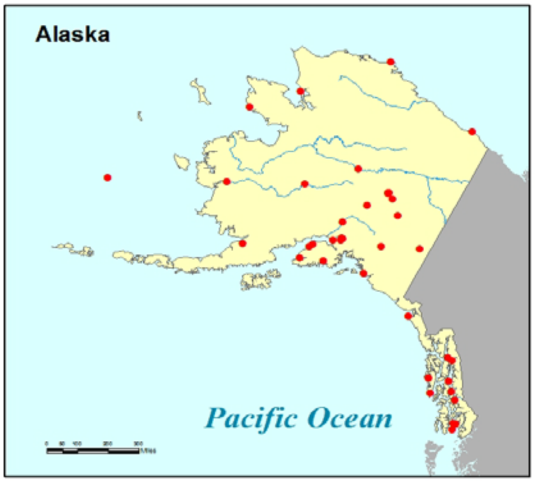
4.0 Results

4.1 Weather Station Distribution

For making accurate zoning maps, the distribution of data points is critical. It is reasonable that, if data point distribution is fairly dense, the accuracy of zoning maps are increased. The following map represents the distribution of the weather stations which provide the data for *Probability Levels For Freeze Dates and Growing Season Lengths* (NCDC dataset 9712C) [1]. Red points are weather stations.

Figure 4-1

Alaska and Hawaii Weather Stations



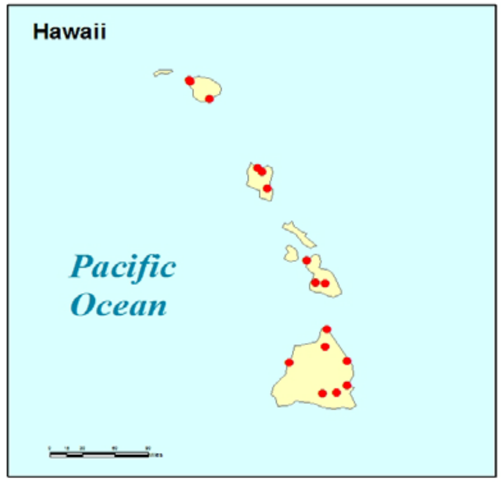


Figure 4-2 Figure 4-3

On the Conterminous United States map (Figure 4-1), although there are some sparse areas, for example Nevada and Wyoming, the distribution is fairly dense and even. It should be noted that there are many counties with no weather stations while other counties have multiple weather stations. There are 3,050 weather stations in the conterminous United States, 40 in Alaska, and 16 in Hawaii.

4.2 Frost Day in Hawaii

Although Hawaii is a part of United States, the geographical conditions of Hawaii are very different from most areas in the North America Continent. After viewing the data set for Hawaii, we removed Hawaii from our research. Hawaii is the tropics – there is only one weather station which recorded below 32F in the observation period, none below 28F, and that weather stations is located at the highest point of all the weather stations in Hawaii.

4.3 Zoning Map

Figure 4-4 provides an example of a zoning map. The figure shows the lower 48 states, illustrating the range of dates which have 10% probability of being 28F or less on a later date. For example, in Arkansas, we can see three different zones. Fayetteville is in the northernmost of these zones. Therefore, during April 16th to April 31st, we have more than a 10% of probability that the temperature will go below 28F.

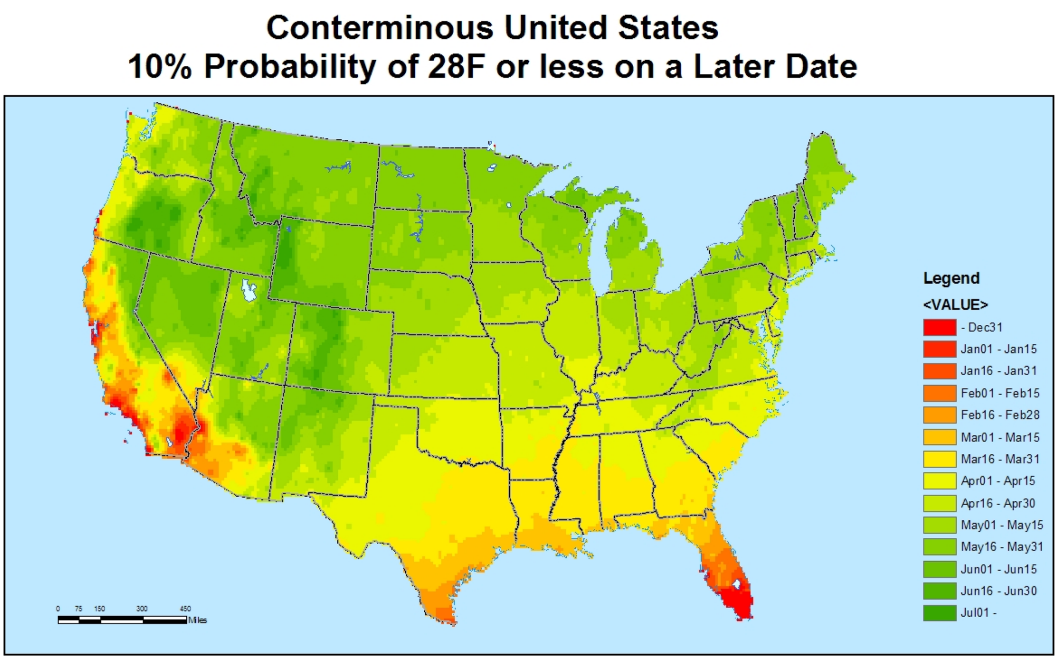


Figure 4-4

4.4 County Level Classified Maps

From the zoning map data, we next created county level classified maps, which provide an average probability for each county (e.g., Figure 4.5). The map closely resembles the zoning map.

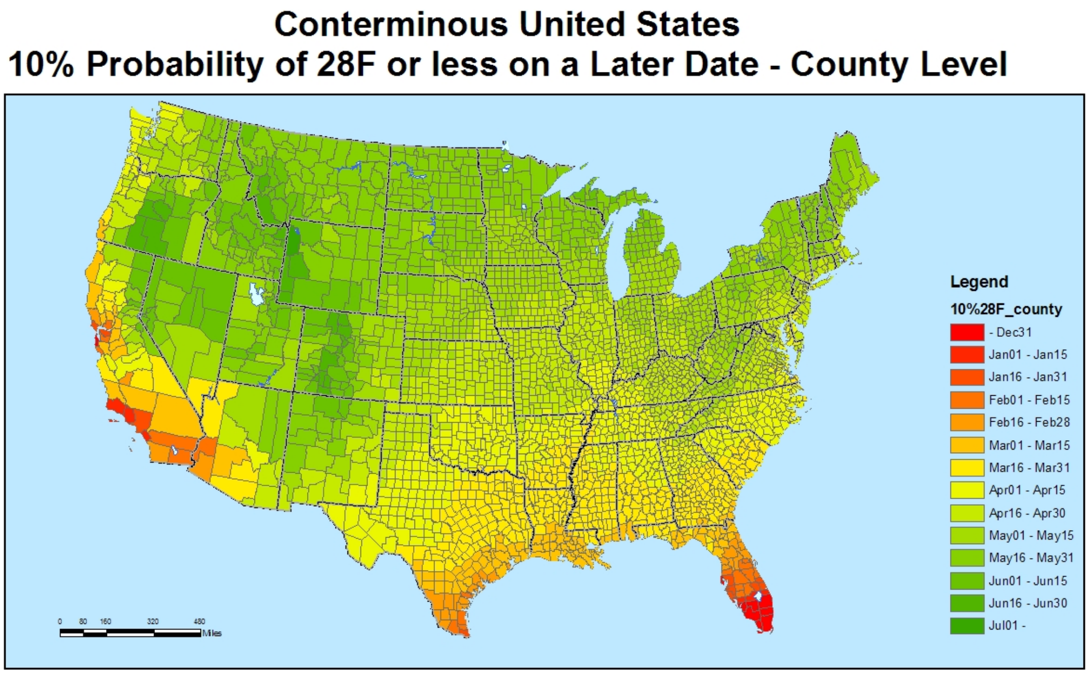


Figure 4-5

4.5 Date Range for County Level Classified Map

To learn how it accurate theoretically, we compared the maximum and minimum date of statistics for each county. If the range is large, the accuracy of the date would be less certain. Figure 4-6 shows this graphically – the dark colored counties, most of the eastern and central area, have narrow date ranges, at most two weeks. On the other hand, many counties in the west have wide date ranges. There are some possible reasons why these counties have wide data ranges. One reason is that county areas in the west are larger than in central or eastern regions, that is, the date range becomes larger if the amount of the data taken for calculation is larger. Another reason is that there are mountains in this area. Elevation has strong effect on the temperature.

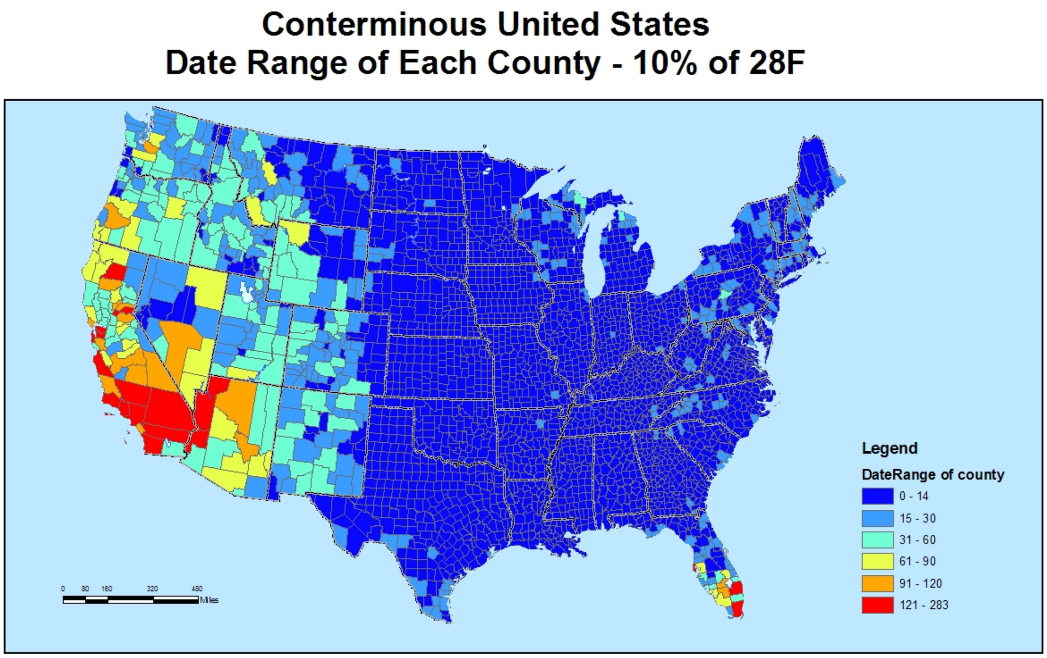


Figure 4-6

4.6 Elevation Map of the United States

Figure 4-7 shows elevation data for the United States. White and dark brown represent mountains or high elevation. Elevation ranges in the west may often help to account for wide temperature ranges within a county.

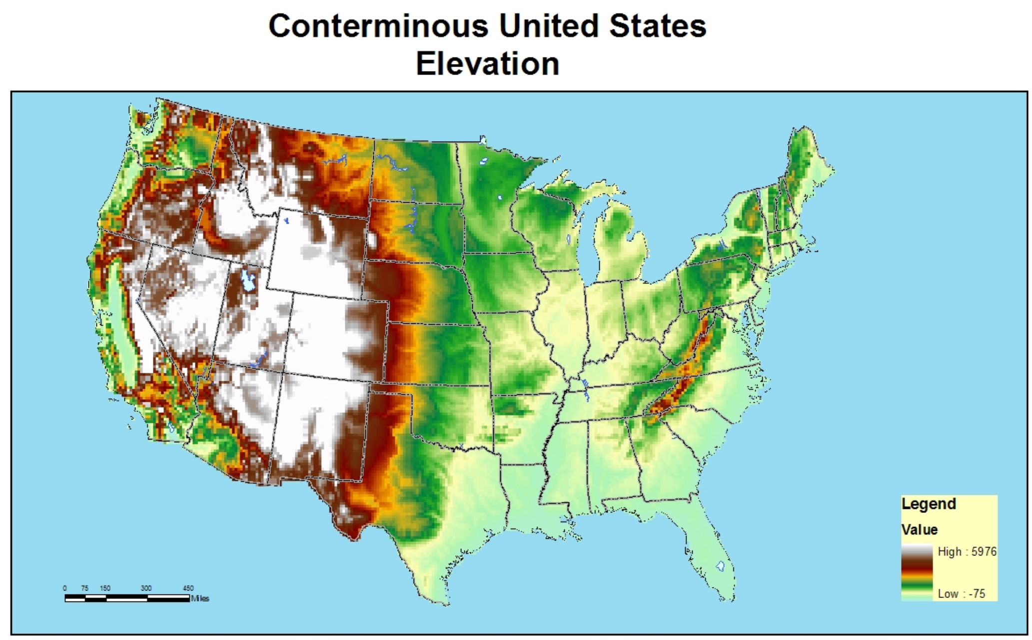


Figure 4-7

4.7 Map of weather station which almost never record below 28F

In Figure 4 –7, we saw red areas, especially in California and Florida. Both locations are warm and have weather stations which only rarely record temperatures below 28F. Figure 4-8 is a distribution map of weather stations which almost never record below 28F (represented by stars) – there are thirty of these. “Almost” means for thirty years, it record below 28F degree zero or only one to three times. These correlate reasonably with the red areas in Figure 4-7. From this analysis, weather in the eastern and central part of county level is more stable and predictable than weather in the west.

Conterminous United States
Weather Stations almost never record below 28F

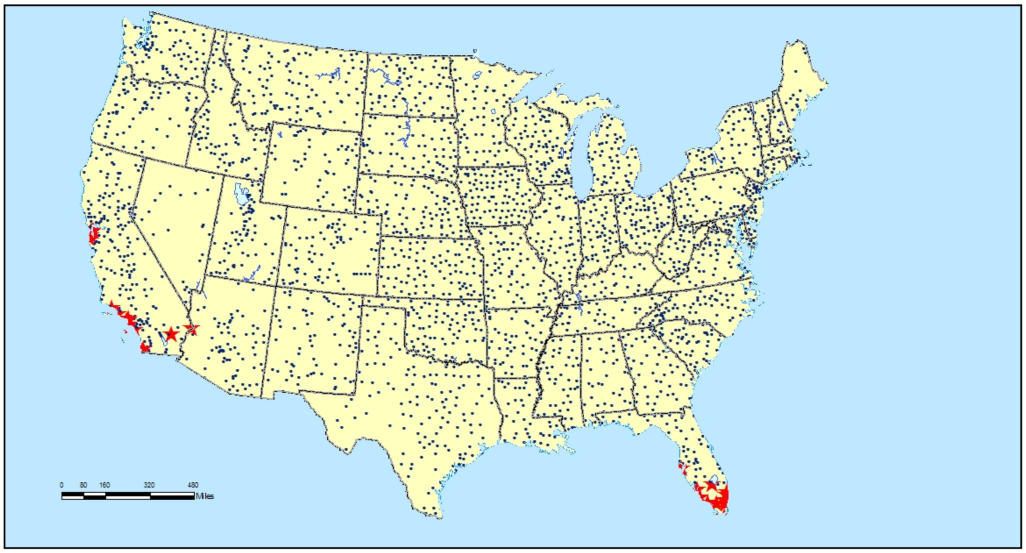


Figure 4-8

4.8 More Calibration Needed

In our project, we defined "frost day" as a day with minimum temperature below 32F degree and "killing frost day" as a day with a minimum temperature below 28F degrees. According to Dr. Klingaman in Horticulture, in Fayetteville, the safe planting date is considered to be between March 25 to 30 for frost-tolerant plants (broccoli, onions, pansies, primroses, etc.) and between April 15 and April 20 for frost-tender plants (tomatoes, most spring bedding plants). We compared this guidance with our maps. From March 25 to 30, the date considered safe for planting frost-tolerant plants, there is still more than 50% chance of temperatures below 28F degree and more than 90% chance of temperatures below 32F degree based on NCDC data. From April 15 and April 20, the date range considered safe for frost-tender plants, the probability to go below 28F degree is 10% to 15% but the probability to go below 32F degree is still around 40% - 50% or more.

Probability	Date Range for 28F	Date Range for 32F
10%	Apr 16-30	May 1 –15
20%	Apr 1-15	Apr 16 - 30
30%	Apr 1-15	Apr16 - 30
40%	Apr 1-15	Apr16 - 30
50%	Apr 1-15	Apr 16 - 30
60%	Mar 16-31	Apr 1 – 15
70%	Mar 16-31	Apr 1 – 15
80%	Mar 16-31	Apr 1 – 15
90%	Mar 16-31	Apr 1 – 15

Table 4-1 Probability and temperature in Fayetteville

From this information, we can hypothesize about this situation. The frost-tolerant and frost-tender plants might be hardier in low temperature than we assume. Another likely candidate is climactic change: The dataset we use for this project covered 1951 to 1980 and may not reflect global warming. Even a degrees in temperature can lead to a significant variation in date range. Of course, it is possible that horticulture guidelines could need revision. More study is needed to resolve these differences.

5.0 Conclusion

With the climatic data set from National Climatic Data Center, we created national to county level zoning maps using geospatial software, and made a probabilistic analysis of those maps to determine "last frost day of the Spring."

The definition of "last frost" is somewhat arbitrary, and there are many indefinite elements botanically and climatically about this problem. These were quantified somewhat by selecting 28 ^{o} F. and 32^{o} F. as definitions for frost-tolerant and frost-tender plants but more work is needed. Possible future work in this area includes:

- using more recent data (assuming global warming is a potential factor);
- more careful analysis of local variations in weather between a weather station and a nursery store location, especially with respect to distance and elevation differences;
- a similar analysis for first frost of the Fall; and
- a web service that makes these maps available to any U.S. nursery.

Acknowledgements

Bruce Firth, Strategy Manager, Wal-Mart, suggested and helped to frame the Last Frost Problem. Dr. Craig Thompson, Computer Science and Computer Engineering Department, University of Arkansas, was faculty advisor and provided guidance on methodology. Dr. Gerald Klingaman, Horticulture Department, University of Arkansas, provided guidance on defining "killing frost." The University of Arkansas Center for Advanced Spatial Technologies provided guidance on geospatial software.

References

[1] *Probability Levels For Freeze Dates and Growing Season Lengths*, Data Set 9712C, National Climatic Data Center, Ashville, NC, 2002.